CHAPTER I

INTRODUCTION

The Shillong - Mylliem area is situated in the Khasi and Jaintia Hills district, which, in turn, forms part of the South-Western plateau region of Assam. The latter is also known as the Shillong Plateau (Fig. 1). The rocks of the Shillong plateau, which is regarded geologically as a part of the Indian Peninsula, have much resemblance with the similar rock types of South India.

The Precambrian geology of the Shillong plateau, with reference to the Mylliem granite and the Shillong Series was first established by Oldham (1858) and later by Medlicott (1869), Bose (1901), Palmer (1923), Dasgupta (1934) and others, who believed that the granite is of intrusive nature. The present author selected the Mylliem granite with the surrounding metasediments and the basic rocks for detailed petrological studies with particular emphasis upon their relatively little known structure and the geochemistry of the rocks.

Extensive road cuttings provided unusually fine exposures of the granite including outcrops showing critical contact relations. Furthermore, this region proved potentially most significant because the contact relations of the granite with the rocks of the Shillong Series could be clearly studied.
LOCATION OF THE AREA:

The present area lying between Lat. 25°35'30" - 25°26' N. and Long. 91°45' - 91°55' E., covers 232 square kilometers. It forms almost precisely the central part of the Khasi and Jaintia Hills of Assam (Fig. 1). Shillong, the capital of Assam is situated on the northern part of the area while Mylliem state (town) lies in the centre of the area. Laitlyngkot, 28 kilometers on the Shillong-Dawki road roughly marks the southern boundary.

COMMUNICATION AND ACCESSIBILITY:

Shillong is connected with the plain districts of Assam on the north with a good motorable road, the only highway, which acts as the backbone of communication for the area. Although the transport system of the area under examination, except Shillong, is not so well developed, yet some portions of the area is traversed by good motorable roads; connecting Shillong with Jowai on the east, Dawki and Cherrapunji on the south and Mawphlang on the south-west. The Shillong-Cherrapunji road passes through the heart of this area. The village foot paths are of much importance and provide an access to many remote areas. The development of communication is greatly hindered by topography, which is controlled by high hills and deep gorges.
FIG. 1

MAP OF A PART OF KHASI AND JAINTIA HILLS

SCALE 2 CMS. = 20 KMS.
PRESENT AREA - HATCHED
METALLED ROAD -
UNMETALLED ROAD ---
DISTRICT BOUNDARY ----

ASSAM
SHOWING
SHILLONG
PLATEAU

MAP OF INDIA

ASSAM

150°
192°
26°

0 800 1600 KMS.

GAUHATI
BARNihat
NONGPOH
UMSNING
DOMMATI

OMAIRANG
MAWPHLANG
SHILLONG
LAITLYNGKOT
JOWAI

RALLANG

CHERRAPUNJI
DAWKI
CLIMATE AND VEGETATION:

The area is situated in the temperate belt, but because of its high altitude, which is nearly 1800 meters above M.S.L., it enjoys a tropical climate. Cool climate prevail throughout the year with fairly dry winter. The coldest month is December with a monthly average temperature of 8.94°C, while the hottest month is July, when the average temperature records 20.83°C. The rainy season begins in the month of June and continues up to middle of October with the maximum rainfall of 46.13 cms. in June. The total annual rainfall is 214.95°C.

The type of natural vegetation is mostly coniferous. Luxuriant growth of pine, especially, on the hill slopes add to the scenic beauty of the place. Small and scattered bushes seen in the dry season covers wide areas during rainy season.

The most suitable time for field work in the area is from November to March.

REGIONAL GEOLOGIC SETTING:

Published reports of pioneer geologists like Oldham (1858), Medlicott (1869), Dasgupta (1934), Ghosh (1940) and others, give a general idea of the rocks occurring in the Shillong plateau. The plateau stands on Archaean gneisses,
granite gneiss and schists, which are well exposed on the northern and western part. Huge deposits of quartzites with conglomerate, phyllite and schists belonging to the Shillong Series of rocks overlie the gneissic complex and occupy the central part of the plateau. First intrusive into the rocks of the Shillong Series is a type of basic rocks known as the Khasi greenstones or epidiorites, while a coarsely porphyritic granite known as the Mylliam granite intruded these rocks at a later date during the Precambrian period. The southern fringe of the plateau shows the occurrences of trap rocks (Sylhet trap) of pre-upper cretaceous age, which is overlapped by the sandstone formations belonging to the cretaceous age. The Therriaghat formation comprising of sandstone, coal and limestone without any appreciable break succeeds the cretaceous formations. The general stratigraphy of the Shillong plateau is as follows:

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Nummulitic Limestone
Cherra Sandstone
Sylhet Trap
Mylliam Granite
Khasi Greenstone
Shillong Series
Granite gneiss and Schists.
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The present area includes the Mylliam granite, the Khasi greenstones and the rocks of the Shillong Series.
FIG 1. BLOCK DIAGRAM OF SHILLONG-MYILLEM AREA SHOWING THE UNDERLYING GEOLOGICAL STRUCTURE. NOTE THE GRANITIC AREA AT THE CENTRAL PART.

(HORIZONTAL SCALE 2/96 CM = 1/609 KM.)

SHILLONG SERIES
SHILLONG GRANITE
PHYSIOGRAPHY OF THE AREA:

The area under investigation is regarded as the dissected remnant of a peneplane surface. The summit level and the general undulating character of the surface suggests long-continued fluvial erosion in this area. Shillong Peak (1963.2 meters) situated at about 8 kilometers S.W. of Shillong, is the highest point in the whole of Shillong Plateau. Another important peak is Laitkor (1960 meters), about 4 kilometers to the N.W. of the former peak. The two are joined by a ridge, which runs in NE-SW direction, parallel to the trend of the rocks. This ridge is called the peak ridge. It forms the divide between the north flowing and the south flowing streams originating in the area (Fig. 2).

The topography in the quartzite country is highly undulating with the formation of deep gorges due mainly to river cutting. Two such gorges are seen, one along the course of the river Wah Umium on the north-western part of the area and the other on the extreme south. A stream called Umban, originating in the Shillong Peak (25°31'54" : 91°51'10") and Upper Shillong (25°33' : 91°50'45") region flowing towards west to join the river Wah Umium produced a series of falls in its course ranging from 12 meters to 60 meters, of which Elephant falls in Upper Shillong is well known. The whole course of Umban lies in the quartzite
terrain and these have formed probably due to differential erosion along the zones of structural weakness. Near Elephant falls the rocks dip towards SE while the stream flows towards NW. This is, therefore, an anti dip stream at this place.

The topography in the granitic country is much gentler compared to the quartzite country. The central and southern part of the granitic body is highly dissected and is covered with rounded hills; convex slopes predominate the landscape. Steeper slopes occur only near the main streams particularly near the granite - quartzite boundary in the south-west.

The northern boundary of the granite is demarcated from the quartzite country by the rivers Umbaniun and Umiew. A strip of level country lies along these two river valleys. It appears that these rivers have formed this strip of plain land by erosion and ultimately shifted their course towards the contact zone of the quartzite and the granite. Therefore, these rivers are regarded as subsequent rivers.

The most important feature of geomorphological interest lies in the fact that the two rivers Umbaniun and Umiew in their upper courses follow the contact plane along the northern, north-eastern and north-western boundary of the granite but on the southern, eastern and western part of the granite, the rivers flow through the granitic country.
This anomalous behaviour of these rivers might result at least due to two factors. Either, the rivers follow the zones of structural weakness, such as, the major joints in the granite or these rivers were originally developed on the younger rocks (See p. 22) and later, when they were eroded and washed away, the rivers were superimposed on the granite. Both the possibilities hold good in this region, since the main course of the river Umiew follow the trend of the longitudinal joints in the granite, while the existence of a sedimentary cover upon the granite is indicated by the presence of outliers of the Cherra sandstones on the granite.

WEATHERING OF THE ROCKS:

The area experiences high rainfall during monsoon as it is nearer to the places (Cherrapunji and Mawsyndram) where the average rainfall throughout the year is highest in the world. The difference in the day and night temperature is also considerable. Denudating agents acting on the rocks of this area for ages have moulded the present form of topography in the area.

The most interesting feature of the quartzites of the Shillong Series are the valleys, which are more or less narrow and elongated and run parallel to the direction of strike of the formation. The quartzites possess well defined joint systems (Plate 1 A), the most prominent
sets being those, which are parallel and perpendicular to the bedding planes. Weathering agents acting along the joint planes ultimately dislodge the rocks from the original position in rectangular slabs or blocks. As a result of high rainfall, the compactness of the quartzites in general, is lost, and at places they become loose and friable. In some places, certain bands of quartzite become more weathered than the top and bottom beds. This is seen in the case of graphitic quartzite in a quarry cutting at Upper Shillong. These quartzites are much more altered and friable but towards the top of these exposures, hard splintery quartzites are found which do not show decreasing coherence of their compactness due to alteration.

The action of rain water has made the surface of the quartzite rugged and imparted to it a deep brown colour, due to the formation of a coating of iron oxide. This is seen on the bare outcrops of the rock long exposed to weathering and sunlight. The leaching action of water in the weathered quartzite, which resulted in the formation of brown ferruginous bands (Plate 18) forms another important feature in the weathering of these rocks. These bands, besides following the joints and cracks are also seen to occur in more or less concentric rings and also in irregular nature.
In the weathering of the conglomerates it is observed that the cementing material is generally affected by the weathering agents, which partly goes into solution forming loose aggregates of pebbles. The decayed cementing material or the rock waste become a part of the soil.

The Khasi greenstone is a compact hard rock and is less resistant to weathering than the quartzite. The rock has well defined closely spaced joints. Weathering agents, generally water acts along these weak planes and break them easily. Greenstone alters to a deep brown earthy matter (soil) as a result of long decay in highly moist areas, as well as, those underlying a thin wet soil cover. Spheroidal weathering and exfoliation is also seen in Khasi greenstones.

The major portion of the area is covered by the porphyritic granite. The most typical feature of these granites are the spheroidal weathering (Plate 10), which indicates the presence of good joint systems, the channelways for the weathering agents to form spheroidal boulders. Small and big boulders of granite, which are more or less fresh, rest over the weathered base of the same composition. Granite when highly weathered loses its biotite content which are subsequently washed away, feldspars are kaolinised, while quartz being more resistant to weathering persists. Exfoliation or splitting off of thin
sheets from the surface of the granite blocks as a result of differential expansion and contraction due to variation of temperature, is a common feature seen in the spheroidal boulders.

**Previous Work:**

As early as 1851-52, Olmham (1858), examined the rocks of the Shillong-Cherrapunji area and distinguished two types of metamorphic rocks in the Khasi Hills—an older and more altered group of rocks, traversed by finely crystalline granite, and an younger group of rocks, which is "essentially slaty, consisting of blue and grey flaky schists with some micaceous and quartzose layers."

Kedlicott (1869), mapped a portion of the Shillong plateau along Shillong-Cherrapunji tract and wrote an account of the rocks of that area. He stated, "the Shillong Series consists of a considerable thickness of quartzite, locally largely conglomeratic". He also noted compact, sharply bedded varieties and also coarse forms, in which, false bedding is clearly seen. About the Khasi greenstones, he said, "it is undoubtedly an igneous rock, a dense, basic trap in which the feldspathic element is subordinate". Regarding the granites, which was described as 'granite of Molim', he concluded, "there can be little doubt that these granite masses are truely intruded", and attributed to it a
younger age than the Khasi greenstones.

Bose (1901-2) observed xenoliths of quartzite of the Shillong Series in the granite, which was found to cut obliquely across the strike of the rocks of the Shillong Series.

Palmer (1923) stated that "the granite is a structureless aggregation of large porphyritic pink orthoclase, quartz and biotite. Sometimes by a reduction in the amount of quartz the rock approaches a syenite. The grey granite seems merely a variety of the pink".

Bradshaw (1925) confirmed the early reports of Palmer that the granite is foliated to the south, the foliation being an original structure and it was induced at the time of intrusion when the rock was in a semi-molten condition.

Das Gupta (1934) agreed with the views expressed by the earlier workers and stated that the presence of xenoliths of quartzite in granite, the cross-cutting relationship of granite with the quartzite and the very coarse granitic structure of the rocks, point to the intrusive nature of the granite. It was further confirmed by the changes the granite has produced in the older rocks where they have been affected by the intrusive granite. He also noted that "the general lie of the granite is fairly parallel to the tectonic axis of the Khasi Hills".
Chatterjee (1937-38) also supported the view that the Myllian granite is intrusive in the quartzites of the Shillong Series. He stated that "there are typical tension fractures in the granite filled up in many cases by aplites, pegmatites and quartz veins and later shifting of these veins suggest displacements in the granite. Chatterjee observed flow of feldspar phenocrysts mostly along N-S with varying angles of pitch - generally towards north.

A.M.N. Ghosh (1940-41) in his article on the Cherra sandstone had noted the occurrences of Eocene sediments east of Laitlyngkot. He considers that the isolated outcrops of the Cherra sandstone, which occur further north of Cherrapunji are all outliers of the Cherra stage.

Pascoe (1950) in his discussion on the Myllian granite has stated that "the dip and strike of the Shillong quartzites along the granite boundary are quite independent of the granite, and the contortions in the quartzites must have been effected before the granite was intruded".

Krishnan (1968) is of the opinion that the Shillong Series overlying the gneissic complex is the equivalent to the Dharwars, which was first intruded by the Khasi greenstones and later by the Myllian granite. The rocks of the Shillong Plateau near its western end show the continuation of the Satpura trend while more to the east they show eastern-ghat trend.
After a preliminary study of the area, Rahman (1958), observed that the emplacement of the Mylliem granite might have taken place in a synclinal basin running in an east-west direction. It was also suggested that the flow of the granitic magma pushed apart the country rocks, throwing them into open, gently plunging folds, trending roughly parallel to the trend of the pluton.

Choudhury and Rahman (1959) studied the basic xenoliths occurring in the granite and noted that they were affected by the granitic fluid and a hybrid rock of dioritic composition was produced. The Mylliem granite was considered a high level pluton. The elongation of the xenoliths parallel to that of the feldspar phenocrysts indicate that the emplacement of the granite took place while the magma was still mobile.

Chowdhary (1960) recorded two major movements in the metasediments around Shillong. The first was eustatic and the second was dynamic. The later movement according to him, originated with the forceful intrusion of the granitic magma with a tectonic transport towards north-west.

Chowdhary and Chowdhary (1960) reported the occurrence of graphite in the quartzites of the Shillong Series, and suggested an inorganic origin of these carbonaceous matter.

Chowdhury (1962) made petrological study of the Khasi greenstone and stated that "the Khasi greenstones are
derived from basic igneous rocks of gabbroic composition and had undergone regional metamorphism along with the quartzites of the Shillong Series prior to the intrusion of the Myllian granite. The mineralogy indicates that the Khasi greenstones belong to the Almandine-amphibolite facies."

Choudhury and Rahman (1967) studied the contact effects of granite on the surrounding quartzite from a series of samples of quartzite collected from different distances of the contact plane with the granite and noted the conversion from sericite to muscovite and recrystallization of quartz with the total obliteration of the original clastic nature near the contact.

METHODS OF INVESTIGATION:

Field Technique: The field work was carried out during the years 1965, 1966 and 1967, mostly in the months of May, June, October and November, and altogether nine months were spent in the field. An area of 232 square kilometers was geologically mapped.

An enlarged map of the area under review was prepared on an 1:160,000 scale from 1" : 1 mile topo sheets (Nos. 78 O/14, & 78 O/15), published by the Survey of India during 1910-11, and later corrected in 1936-37. No change
in the topography has been observed except slight changes in the direction of small nalas.

All possible field relations of the rocks were investigated and every minor and major structure were examined and noted. Finally, the outcrops of the rocks with their structural features and the junctions of the different rock formations were plotted on sec. 1:6000 map (map 1).

In the quartzites, surrounding the Myllian granite, oriented samples were collected from places across the strike of the formation and also from the limbs of the folds. Besides, samples of quartzite were collected from places near the contact with the granite and at certain intervals, from places of increasing distances from the granite. Different types of lineation, such as mineral lineation, minor folds, slickensides etc., were measured so also the sets of joints in the quartzite.

For statistical analysis of preferred orientation of minerals in the porphyritic granite, direction of the longest axis of the feldspar phenocrysts were measured on the three faces of the granite exposures, wherever possible. Oriented samples were also collected from those places. The lengths and breadths of the phenocrysts of potash feldspars more than 20 sq. mm. in size within areas of 900 sq. cm. were measured at many places to incorporate the value in the thin section modal analysis of the granite.
Representative samples of pink and grey porphyritic granite from exposures at different localities were collected for petrographic studies and chemical analyses.

Samples of Khasi greenstones were collected from different localities within the area to study the petrography and the contact effects by the granite. Samples of politic rocks were also collected from the successive stratigraphic horizons to study the contact metamorphic effects by the Khasi greenstones and the granite. The elongation direction of the pebbles of the conglomerate were noted besides collecting pebbles of different character for petrographic studies.

Occurrence of xenoliths in the Khasi greenstone and more particularly in the granite were noted and samples were collected for petrographic studies.

Sketches and photographs were taken in the field wherever found necessary.

Laboratory Methods: Thin sections were prepared of the rock samples collected in the field and studied under the microscope along with their megascopic characters to corroborate with the field observations.

Oriented thin sections, 25 from the quartzite of the Shillong Series, 10 from the Kylliam granite and 3 from the xenoliths in granite, are prepared from the respective
oriented samples of those rocks, and the optic axis or $c$-axis of quartz is determined with the help of Leitz's 4-axis Universal stage to study the quartz fabric patterns. The quartz poles of each section are plotted separately on Schmidt's equal area projection (net), on the lower hemisphere, and the contour diagrams are prepared. The contours represent lines passing through points of equal concentration.

Volume percentages of minerals present in the various rock types are determined with the help of Swift's point counter. The stage with an east-west point spacing of 0.3 mm. was used with a microscope magnification of $\times 80$ for the quartzites and the Khasi greenstones and $\times 40$ for the granite.

As the granite is very coarse grained and porphyritic, thin sections of the phenocrysts and the groundmass were prepared separately and counted for modal analysis. Thin sections were stained for potash feldspar following the procedure suggested by Chayes (1952) and Rosenblum (1956).

The twinning laws and the anorthite content of plagioclase have been determined with the help of Leitz's 4-axis Universal stage, following the procedure and the curves of Slemmons (1962). $2V$ for microcline and hornblende were also determined.
The study of the grain contacts between the constituent minerals in the granite and the occurrence of albite rims around plagioclase are studied. The thickness (width) of the albite rims are measured with the help of micrometer scale.

Refractive indices of biotite and hornblende are determined by the liquid immersion method.

Block diagrams are prepared according to scale corresponding to the three faces of the granite exposures and the preferred orientation directions of the feldspar phenocrysts are plotted showing their inclinations on the vertical faces to set a three dimensional picture of the flow layers and to determine the angles of pitch of the flow layers.

Poles of joint planes are plotted on the Schmidt's equal area projection net on the conventional lower hemisphere and contour diagrams are made (Billings, 1954).

Chemical analyses of 14 rock specimens have been carried out in order to establish the geochemistry of the different rock types and to trace the variations, if any, within the same group of rocks. For this purpose, 7 specimens from the Mylliem granite, 4 from pelitic rocks of the Shillong Series and 3 from the Khasi greenstones were taken. The selection of specimens is made on the basis of studies in thin sections and from their distribution with respect
to different group of rocks, so that, they are broadly representative of the main rock groups. Specimens from the Mylliem granite are taken covering the entire width of the exposure, while pelitic rocks are collected from least metamorphosed phyllite through intermediate zones to highly metamorphosed contact hornfels. The Khasi greenstones are taken from different exposures of the rocks lying at various distances from the granitic body.

Crushing is done in high grade special steel rock crusher (Groves, 1937) followed by an agate mortar and pastle till all the material passed through a 100 mesh sieve. In the case of coarse grained porphyritic granite where the phenocrysts are too large, crushing is started with very large samples (average size 15 cm. x 15 cm. x 10 cm.). After some amount of crushing they are first made to pass through a 18 mesh sieve and the volume is reduced by coning and quartering of the bulk of the coarse powder and then further crushing is followed to pass them finally through a 100 mesh sieve. The small amount of powder required for the analyses is obtained by coning and quartering of the bulk of the fine powder. The analytical procedure is based entirely on the rapid methods of Shapiro and Brannock (1962). The main instruments used include Mettler electrical balance (accurate up to the fourth place of decimal), Carl Zeiss spectrophotometer (VSU-I), and Dr. Lange's flame photometer (Model-6).
Nickel and Platinum crucibles (for solution A and B respectively) and polyethylene bottles for storing the solutions (including the standards) have been used. Suitable samples of the Bureau of Analytical samples (U.K.) and two rock samples (analysed by Dr. C.C. Bhattacharjee at Glasgow University, U.K.) have been used for control. A.R. and G.R. grade chemicals (mostly of B.D.H. and S. &s) have been used as reagents as well as in preparing standard solutions.

The analyses are expressed as weight percentages of the oxides and include the following: SiO₂, TiO₂, Al₂O₃, Fe₂O₃, FeO, MgO, MnO, MgO, CaO, Na₂O, K₂O, P₂O₅, and H₂O. The results of the analyses are arranged in tables in the description of the respective rock types. Averages for each group of rocks as well as average analyses of similar rocks are also given for comparison. The results obtained are given without recalculation to 100 and thus the totals, in most cases, differ (by as much as 1%) from 100.

Nigglí values (Nigglí, 1954 pp. 12-16) and C.I.P.P. norms (Johannsen, 1939, pp. 88-94) are calculated from the chemical analyses. These are also given in tabular form in the respective places.
A. Well jointed Shillong quartzite exposed at Beadon falls area (26°35'15" : 91°32').

B. Ferruginous bands in graphitic quartzite at Upper Shillong (25°33' : 91°50'45'N). The bands are prominent along fractures and joint planes.

C. Spheroidal weathering in the Mylliem granite.
   A typical landscape of the granitic terrain.
   Big rounded boulders of granite rest on weathered granitic soil.